EDUCATION IN THE FIELD OF OCEANOGRAPHY

THE UNIVERSITY
OF MICHIGAN

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HEARING

BEFORE THE

SUBCOMMITTEE ON EARTH SCIENCES

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS

U.S. HOUSE OF REPRESENTATIVES

EIGHTY-SIXTH CONGRESS

FIRST SESSION

ON

H.R. 6298

AUGUST 25, 1959

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EDUCATION IN THE FIELD OF OCEANOGRAPHY

TUESDAY, AUGUST 25, 1959

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON EARTH SCIENCES OF THE
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C.

The committee met at 10 a.m. in room 214–B, New House Office Building, Hon. Overton Brooks (chairman of the subcommittee) presiding.

The CHAIRMAN. The committee will come to order.

The committee has under consideration this morning H.R. 6298.

(The bill referred to follows:)

[H.R. 6298, 86th Cong., 1st sess.]

A BILL To amend the National Science Foundation Act of 1950 to provide financial assistance to educational institutions for the development of teaching facilities in the field of oceanography, and to provide fellowship for graduate study in such field

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the National Science Foundation Act of 1950 is amended by redesignating sections 15, 16, and 17 as sections 16, 17, and 18, respectively, and by inserting after section 14 the following new section:

"ASSISTANCE TO EDUCATIONAL INSTITUTIONS AND GRADUATE STUDENTS FOR THE TEACHING AND STUDY OF OCEANOGRAPHY

"SEC. 15. (a) (1) The Foundation, in carrying out its function of promoting education in the sciences, is authorized to make grants to accredited nonprofit institutions of higher education to assist them in carrying out programs for the acquisition and development of facilities for the teaching of oceanography.

"(2) To be eligible for a grant under this subsection, an institution of higher education must submit to the Foundation an application setting forth a program, for the acquisition and development of new or additional facilities for the teaching of oceanography, which meets standards established in regulations prescribed by the Foundation. Such application shall contain adequate assurances that any grant under this subsection will be used only for faculty salaries, equipment, and other expenses arising from or attributable to such program, and that the institution will comply with the regulations prescribed by the Foundation to carry out this subsection.

"(3) Grants under this subsection shall be awarded in such amounts and to such institutions as will result, in the judgment of the Foundation, in the most rapid and effective expansion of facilities for the teaching of oceanography at all appropriately located institutions throughout the United States, giving particular consideration to institutions which can provide for their students who are studying or preparing for study in the field of oceanography the most well-rounded education in the related basic sciences and the practical advantages of affiliation or association with marine laboratories and other related research organizations.

"(4) The regulations prescribed by the Foundation to carry out this subsection shall include provisions designed to insure that such grants are used only in the manner and for the purposes set forth in this subsection, but shall not otherwise

provide for or permit any interference with or control of the faculty or curriculum of any institution to which such a grant is made.

"(5) In the event of the failure of any institution of higher education to comply with the regulations prescribed by the Foundation to carry out this subsection, the Foundation may terminate or suspend any further payments to such institution under this subsection.

"(b)(1) The Foundation, in carrying out its functions set forth in section 3(a)(4) and to assist in meeting the need for increased numbers of qualified oceanographers, is authorized to award graduate fellowships for study in the field of oceanography. Except as specifically provided in this subsection, such fellowships shall be awarded in the manner and subject to the conditions provided in section 10 and the regulations prescribed by the Foundation thereunder.

"(2) The fellowships provided for in paragraph (1) shall not exceed eighty (which shall be in addition to any fellowships awarded under section 10) in any one year, and any such fellowship shall be available only for enrollment in a graduate program of study in oceanography, for an aggregate period not exceeding five years, at one or more accredited nonprofit institutions of higher education selected by the student and approved by the Foundation upon its determination that the program of study in oceanography at each such institution meets standards established in regulations prescribed by the Foundation.

"(3) Each person awarded a fellowship under this subsection shall receive for each academic year thereunder a stipend of not less than $3,500 nor more than $4,000, which shall be payable in such manner and at such time or times as may be provided in regulations prescribed by the Foundation, and which shall be payable only during such period as the Foundation finds that he is maintaining satisfactory proficiency in (and devoting essentially full time to) the program of study for which the fellowship was awarded.

"(c) Notwithstanding any other provision of law, the Foundation may make grants to an institution of higher education as described in subsection (a) under an agreement providing that such grants will be made (subject to subsection (a)(5)) over a period of years sufficient to permit the full development of the program set forth in its application made under that subsection, and may award fellowships as described in subsection (b) under an agreement providing that the stipends thereunder will be paid (subject to subsection (b)(3)) over the full period of the fellowship.

"(d) Of the amounts appropriated for any fiscal year pursuant to section 18, not more than $500,000 shall be available for grants under subsection (a) of this section and not more than $300,000 for graduate fellowships under subsection (b) of this section."

SEC. 2. (a) Section 10 of the National Science Foundation Act of 1950 is amended by striking out "section 17" and inserting in lieu thereof "section 18".

(b) Section 17(b)(1) of such Act (as redesignated by the first section of this Act) is amended by striking out "section 15(h)" and inserting in lieu thereof "section 16(h)".

The CHAIRMAN. In view of the many new approaches to scientific problems and new techniques being developed in the earth sciences, it appears that it would be of great interest and great benefit to the scientific community and to the Congress, as well as lay citizens, that this committee should make a study of the earth sciences. Accordingly, I have appointed a special subcommittee known as the Subcommittee on Earth Sciences.

The primary and basic earth sciences are geology, geophysics, geochemistry, oceanography, and meteorology. No doubt at present our educational institutions and scientists are devoting greater attention to geophysics and geochemistry, and we find that many new techniques for the application of physics and chemistry to the study of the earth have resulted in giving these two fields added impetus. The scientific community feels, however, that the study of oceanography and meteorology are both presently lagging behind the other areas. The importance of the earth sciences can be readily noted by a review of the Berkner Commission report dealing with the Geneva meetings having to do with the detection by seismology of atomic tests. The

report of this Commission calls for a further study of underground seismology, a subdivision of our main category of geophysics. The very nature of the difficulty of detection of such atomic tests shows that this requirement is a pressing need from the standpoint of defense.

We in the Science and Astronautics Committee have a very definite interest in the area of meteorology, with reference, particularly, to our space program and the weather satellite. In the practical application of these areas of science, all of us are familiar with the ever-increasing perfection of geology and its application in industry, with particular reference to the oil and gas industry. In the field of oceanography, few of us realize that two-thirds of the earth's surface is covered by the waters of the sea, and that these waters themselves play a major role in governing our climate, providing transportation and nourishment, and traditionally they have provided protection against military attack. It is with this in mind that we have scheduled these hearings on the earth sciences and that we open this series of hearings with a hearing on oceanography this morning.

Our first witness is Dr. Gordon A. Riley, associate director, Bingham Oceanographic Laboratory, Yale University, and a member of the National Academy of Sciences—National Research Council Advisory Committee on Oceanography.

We are happy to have Dr. Riley here this morning. As I understand it, the doctor's statement will be more or less general, covering the field of earth sciences.

Mr. HECHLER. Before you begin, would you care to add the oil and gas industry to the coal industry in your statement?

The CHAIRMAN. That should be added; that is correct. We have a resolution, by the way, before this committee covering the coal industry, and one covering the oil and gas industry.

Mr. HECHLER. Thank you, Mr. Chairman.

The CHAIRMAN. Dr. Riley, do you have a prepared statement?

STATEMENT OF DR. GORDON A. RILEY, MEMBER OF THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL ADVISORY COMMITTEE ON OCEANOGRAPHY, AND ASSOCIATE DIRECTOR, BINGHAM OCEANOGRAPHIC LABORATORY, YALE UNIVERSITY

Dr. RILEY. Yes; I do. My prepared statement was particularly on this bill, H.R. 6298. Would you like me to read the prepared statement first?

The CHAIRMAN. Yes. I think that that would be preferable.

Dr. RILEY. Then I will talk a little about the problems of oceanography and geophysics in general.

As you know, the Committee on Oceanography of the National Academy of Sciences has recommended that rather large sums be appropriated to subsidize both the teaching of oceanography and the support of competent graduate students. We recommended that the fellowship program be handled through the National Science Foundation. We were aware that our recommendation violated certain policies of the Foundation with respect to the size of the stipends requested and particularly with respect to singling out a certain field for special

support. We expected some opposition. Indeed, I tell you frankly that the recommendation, although deemed necessary, was repugnant to some members of our committee. We and the National Science Foundation are essentially the same kind of people. Trained in the university tradition, we respect all kinds of scholarly endeavor and can find no scholarly reason for favoring any one discipline.

Why, then, did we vote this recommendation? There are two reasons. One can be disposed of quickly because it has already been given so much space in our report. We are deeply convinced that our country's defenses will be more secure, and our long-term economic status will be more sound, if there is a considerable expansion of oceanographic effort during the next few years. We believe this to be a practical need which must override purely academic considerations. The expansion that we urge can only be accomplished by producing more oceanographers than we are able to produce now.

In the second place, oceanography, and to some extent other interdisciplinary fields, such as meteorology and geophysics, are handicapped in their efforts to support their graduate students, as compared with basic disciplines such as physics and biology. We are poor relations, and the money that we are requesting for student support is necessary in order to correct the situation.

The reasons why this is so are complicated. To make you understand the picture clearly I need to tell you how we go about producing oceanographers and how our graduate students are supported.

You understand, of course, that oceanography is a concerted attack by any and all sciences on problems of the ocean. A competent oceanographer must have a thorough grounding in a basic science of his choice and as much knowledge of the others as he can acquire within the framework of ordinary academic training. If a young man has been well advised, he takes care of these prerequisites at the undergraduate level, but often we must require students to make up deficiencies in graduate school, thus adding to the length of their training period. As to graduate training in oceanography, I quote a paragraph from chapter 8 of the Committee report. I think it is permissible to quote this in a personal statement, since I wrote the paragraph myself.

> The type of graduate education varies widely. Some universities offer a full course and a degree in oceanography. Others offer a degree in a basic scientific discipline, with the oceanographic program consisting of two or three courses and thesis supervision. Opinions differ as to whether the major emphasis at this level of training should be on the basic dicipline or on the more specialized professional aspects of oceanography. Thus, the young oceanographer is not a standardized product. This is probably a healthy situation in any interdisciplinary profession, leading to diversification of knowledge, interests, and technical skills. However, it must be admitted that thorough education in both oceanography and basic science cannot be accomplished within the usual span of graduate study. Postgraduate study and on-the-job training are generally necessary.

In short, it is a long and grueling course, and it is made more so by the fact that the fieldwork associated with thesis research is likely to be more time-consuming than the laboratory experiments of the basic disciplines.

Next let us consider the problem of financial support; first, in general terms of graduate students in all disciplines. Most of them earn their living as teaching assistants. This is part-time work—

12 to 18 hours a week—supervising undergraduate laboratories, grading papers, and other menial but necessary teaching chores. The salary is not magnificent; $1,500 to $2,000 a year plus tuition is typical of most universities.

Then there are research assistantships, paying about the same or a little more and generally requiring about the same amount of work. These are mainly derived from grants and contracts obtained by departmental staff members, the majority from Federal sources of one sort or another.

Thirdly, there is a graduate student elite class. The most brilliant 5 to 10 percent can win fellowships from the university or from several Government agencies. These generally pay a little more than teaching assistantships and require no supporting work.

These are the main sources of financial aid, although a number of minor sources are discovered from time to time. In almost every case there is rather minimal support for one person. A couple can live in reasonable comfort if the spouse has a job. But there is hardly a professor in the land who has not faced the dreary spectacle of a student with a pregnant wife. What should be a source of great happiness in any family is a dreaded occurrence in the life of a graduate student. It generally means dropping out of school, or a proverty-pinched, prolonged existence at the graduate level while the student spends extra hours earning money and has less time for studies.

Most of these young people see it through, for better or for worse, because they are dedicated scientists. But is it right to turn our intellectual elite into second-class citizens? And, if we want to increase our output of scientists to any great extent, we are going to have to promote them to the status of first-class citizens. This is a general indictment of the whole system—all of the disciplines—but it is the kind of thing our Committee had in mind when we recommended stipends of $3,500 to $4,000 a year.

Now for the particular problems of the oceanographers. One university has an undergraduate curriculum in oceanography, but all other university departments of oceanography are exclusively for graduate students. With no undergraduates to teach, these students are deprived of what otherwise would be their readiest source of income.

In my own university, prospective oceanographers are members of a basic discipline and are eligible for teaching assistantships. But here, as in strictly oceanographic departments, there is another problem. Three of our current roster of seven graduate students are conducting or have conducted their theses research under circumstances which preclude their supoprt by teaching or research assistantships. One spent a year at ice island T–3 in the Arctic and is now at weather station Alert. One did his research in the waters of Bermuda. A third is working not far away in Connecticut waters, but so intensively during certain seasons that he cannot maintain a schedule of assigned work at the university. Thus, nearly half of our students have been cut off from the common sources of income for a considerable part of their graduate student career. We have managed to support them in one way or another, often with considerable sacrifice

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of private funds that we would prefer to spend otherwise. The point is that we cannot expand significantly without outside support.

All of these difficulties could be removed by enactment of H.R. 6298. Under the present system we decide in departmental staff meeting whom we will recommend for fellowships from NSF or other agencies. They are the top 10 or 15 percent of our student body. We know that there is no point in recommending a man unless we can recommend him highly. With limited funds, NSF must pick the best people.

But all of our students who make the grade are competent people. They are required to demonstrate scholarly knowledge and imagination in research. Our recommendation emphasizes that all such students should be eligible for support if we are unable to take care of them in other ways.

I recall a graduate student who was with me for 2 years some time ago. He acquired family responsibilities. We had no job at the time that would support him properly, so he went to another university. He took an almost full-time job as a research assistant. He managed to take a course or two from time to time and did a little thesis research when he could. This year he got his Ph. D. after 11 years as a graduate student. He is going to be an able and dedicated scientist, although admittedly he was only an average student. This is the kind of man who desperately needs H.R. 6298.

Finally, I mention briefly the other recommendation—for Federal support of teaching facilities. Without going into the situation fully, let me just say this: Already, universities have found themselves unable to maintain adequate teaching staffs with private funds. Increasingly, junior staff members are being supported by Federal research grants and contracts. It is an awkward situation, fraught with insecurity. It will become more awkward with further expansion of teaching facilities. Our recommendation simply asks for honest recognition of the importance of teaching, and financial support on a sufficiently long-term basis so that the universities, in turn, can guarantee salaries for a specified contract period.

The CHAIRMAN. Doctor, we want to thank you for a very fine statement. You are from Yale University?

Dr. RILEY. That is right, sir.

The CHAIRMAN. You are directly connected there with the oceanographic laboratory?

Dr. RILEY. Yes.

The CHAIRMAN. How long have you been connected with the oceanographic laboratory?

Dr. RILEY. Practically all of my career, except for a short time during the war years.

The CHAIRMAN. Have you had experience generally with the earth sciences?

Dr. RILEY. I have no immediate personal experience. I am primarily a biological oceanographer, but it is necessary in our field to know what other people in the field are doing, so in conversations with them I have learned a little bit.

The CHAIRMAN. Can you give us a general statement regarding earth sciences? Tell us what it covers generally, if you can. Give

us in a general and brief way an idea of the program we have to outline for this committee in the time that lies ahead.

Dr. RILEY. The earth sciences include all of the studies of the crust of the earth and its interior, the atmosphere and the oceans that cover the earth, and it goes beyond that into a study of problems of astronomy and other aspects of space science.

The CHAIRMAN. Does it cover things like mining? When we refer to seismographic activities, it covers that, does it not?

Dr. RILEY. It covers seismographic activities and geological studies, all of which are essential in the promotion of mining.

The CHAIRMAN. Also it is essential in the location of earthquakes and things of that sort?

Dr. RILEY. Yes.

The CHAIRMAN. Likewise, it might be very important in determining or detecting atomic blasts?

Dr. RILEY. Yes.

The CHAIRMAN. To that extent it would be interesting as a weapon of defense or instrument of defense; is that not so?

Dr. RILEY. Yes.

The CHAIRMAN. What do you mean when you say you are a biological oceanographer?

Dr. RILEY. I mean that I am interested in all life in the ocean, the purely scientific aspects, and also their application to problems of natural resources.

The CHAIRMAN. When you refer to "life in the ocean," do you mean principally fish?

Dr. RILEY. The whole regime of life in the ocean—the green plants, which are the basic food source for all of the animals in the ocean; the small animals, the plankton, the fishes, and the other large animals that live upon the smaller members. We feel as if we should understand all the life in the ocean in order to properly evaluate the natural resources and the optimum level of fishing.

The CHAIRMAN. I judge from your statement you have not made the progress you would like to make in reference to that particular science.

Dr. RILEY. Well, sir, I think there has been great progress in the last 10 years, but we also feel in a good many respects we have not made enough progress and time is running out on us. Perhaps I can explain that with a few simple examples.

We have a wonderful new weapons system. We think it is probably the best weapons system in the world. I am referring to the nuclear submarine armed with rockets, and yet every time you take a weapon system to sea you find that there are oceanographic problems that must be solved in order to use it efficiently. In one respect—namely, the navigation of these submarines—we know about what we need to know in order to navigate effectively, but we also need a very intensive program of surveying of the oceans which cannot be done in less than perhaps 10 or 20 years. The sooner we get started on that the better.

In some other respects we do not know yet exactly what needs to be done. As far as detecting other submarines is concerned, to be sure, our sonar systems have improved a great deal during the past few years since the war, but the ocean still is not what we would like

it to be—transparent to our instruments so that we can detect submarines anywhere in the ocean at any time. This is going to require a major breakthrough and it will be on the basis of basic science which we develop during the next few years, I hope.

The CHAIRMAN. That would be the development of sound waves which will produce echoes from one object to another?

Dr. RILEY. That is a system we have now. We hope that it can be greatly improved, or perhaps someone can dream up an entirely new system that can be more effective.

The CHAIRMAN. In your school, how many people do you have working generally on the matter of earth sciences?

Dr. RILEY. Offhand, I would say perhaps not more than six or eight.

The CHAIRMAN. What is their field of endeavor? What are their studies?

Dr. RILEY. We have one group in the marine physics laboratory, which is primarily a Navy-supported organization, which is working on problems of harbor defense specifically, but it is also doing a lot of basic science on sonar, radar, and various things that are subsidiary to this field. Then in our geology department we have people who are involved in various aspects of geophysics and geochemistry.

The CHAIRMAN. Do you have any long-range programs that you could give the committee?

Dr. RILEY. I would say both of those programs that I mentioned, particularly in geochemistry and harbor-defense work, are long-range programs. In my own laboratory we have a rather long-range program on Long Island Sound which includes some aspects that you might call earth sciences; that is, it includes the physical oceanography of the region, the rate at which the water is transported in and out, the so-called flushing rate of the sound, but primarily it is a biological program. This program has been going on since 1952 and probably will be a long-range effort.

The CHAIRMAN. I have been asking you all the questions. Anyone on the committee who wishes to ask a question, just join in.

Mr. SISK. Mr. Chairman, I simply want to congratulate Dr. Riley on the very fine statement, particularly with reference to the need for some legislation aiding in the education of oceanographers, and I would like to ask this question of Dr. Riley: In the field of oceanography, roughly, how many people do we have today that are what you consider to be competently qualified to do various phases of work needed in this field?

Dr. RILEY. I would have to look in our report to give you a precise answer, but it is of the order of 600 people who are trained at the graduate level and whom I would regard as thoroughly competent. One of the difficulties, however, is that a great many of these people are located in Government laboratories or private laboratories which conduct no teaching program. It is hardly a tenth of these people who are actually involved in teaching, and this is a major problem. We need to build up teaching staffs in universities in order to produce oceanographers at a faster rate.

Mr. SISK. That leads me to my next question, and that is this: What are the opportunities for a man in oceanography outside of Government work as such? Are these extensive opportunities in pri-

vate enterprise or private research? Will you discuss the field of opportunity that is available and which might lead people to seek the opportunity of fellowships in this field?

Dr. RILEY. There is a distinct shortage of trained men. This shortage is extreme in the earth sciences and moderate in biological oceanography. I have never yet failed to place one of my graduate students. Just at the moment, we have been in the market for a physical oceanographer for over a year and have thus far failed to find one. We have two possible candidates who will complete their degrees next year. Such people are snapped up immediately.

Mr. SISK. In other words, there is a lot of opportunity?

Dr. RILEY. Yes. We are not by any means producing enough to fill the demand.

Mr. SISK. In your opinion, insofar as the overall studies in oceanography are concerned—and I am thinking of the whole broad scope of your problem—you have hardly scratched the surface in your studies of the ocean. I am confining this specifically to that portion of the scientific field.

The CHAIRMAN. Rather than the earth sciences?

Mr. SISK. I am talking about that having to do with our oceans, the life in the ocean, and other things concerning the ocean floor, and the problems of the breakthroughs needed in the exchange of signals and so on underwater. Do you feel that we have only scratched the surface in this whole field?

Dr. RILEY. I am sure if you had asked that question of any scientist in any field he would say that he has not scratched the surface yet, but I do think it is particularly true of oceanography.

Mr. SISK. That is really the point that I had in mind; whether or not in this particular field of scientific research and endeavor we are substantially behind, let us say, where we might be in the life science field.

Dr. RILEY. Yes; I think that we are. There is another aspect in which we are terribly behind, and that is the problem of climatology, which is really a combination of meteorology and oceanography. It is quite apparent now that we cannot hope to have any long-range weather forecasting that will be successful until we understand more thoroughly the relationship between the ocean and the atmosphere. We are heavily handicapped by the fact that we do not have any extensive records from the midocean. Until we can develop that field we cannot have any hope of understanding even the next 30 days in our weather, let alone long-range predictions.

Mr. SISK. In other words, then, that ties in pretty much to a problem we have had before this committee quite often, and that has to do with weather satellites. I draw the conclusion from your remarks that even though we may build the instrument and the vehicles and develop the propulsion power to put into orbit or into space vehicles that might give us certain information, we may lack the manpower to analyze and properly use that information; is that correct?

Dr. RILEY. That is correct.

Mr. HECHLER. I was very interested in your statement, Dr. Riley. I think all of us on this committee believe very deeply in expansion in this field. However, I have not been completely sold by your argument yet as to why we should use a rifle approach on oceanography to

the possible exclusion of any other of the earth sciences. In order to put this in a little better perspective, you have used a rather strong word here in the first paragraph of your statement. You say:

> Indeed, I tell you frankly that the recommendation, although deemed necessary, was repugnant to some of the members of our Committee.

I wonder if you could give us an objective statement of the minority views, so we could have a feeling on this committee just how this repugnance was expressed.

Dr. RILEY. It is simply as I stated in that first paragraph. All of us recognize the importance of all sciences and we would like to see increased support for all the earth sciences and any other science. We would prefer not to ask for special treatment for oceanography if there were any other way out of it, but since there is a greater shortage of oceanographers than in any other field, and since we are handicapped in our efforts to support them, and because, as I said, in some practical respects time is running out on us, we felt that it was necessary to make this recommendation.

Mr. HECHLER. Of course, time is running out in many fields in the eyes of a lot of people.

Dr. RILEY. I grant you that.

Mr. HECHLER. You just said that there was a greater shortage of oceanographers than scientists in any other field?

Dr. RILEY. Well, I should not say "in any other field," but I know of few other fields in which it is so easy to place men and so hard to get them.

Mr. HECHLER. I wonder if you could supply for the record later some figures amplifying your answers to Mr. Sisk's question on the number of oceanographers available, the amount of money available, and perhaps some comparative information that would demonstrate and support your statement that there is a greater shortage in this field.

Dr. RILEY. Chapter 12 of our Committee report, of which I can give you a copy, tells about the rate of growth in this field, the number of people that are involved, and the amount of financial support. Now, this does not give the data that you might want to compare with the other fields, and I do not feel competent to give you that. There are National Science Foundation reports that do discuss that kind of thing.

(The information requested will be found on p. 17.)

Mr. HECHLER. In order to support a concerted effort in one field it seems to me that we should have the facts on which we can proceed.

Dr. RILEY. Yes.

Mr. HECHLER. Now, I will ask you a toughy. Is this not in a sense a reflection on the National Science Foundation, whose program is supposed to be broad enough to include the study of oceanography, if we try to single out one field like this? Do you care to comment on that?

Dr. RILEY. I certainly would not want to criticize the National Science Foundation, whom I regard as having done an excellent job. I do feel that they have not fully recognized the special problems of the interdisciplinary fields that I mentioned, and they cannot, within the limits of their act at present, give them special support. I do

think that these fields, such as meteorology and oceanography and geophysics and geochemistry, at the moment need special support.

Mr. HECHLER. Just one further question, if I may. I wonder if you would expand on that phrase—that the National Science Foundation has not fully recognized the importance of oceanography.

Dr. RILEY. It is simply this: Because of the fact that many of these departments are graduate departments, they have no undergraduates to teach and hence cannot supply support for their students in the ordinary way. These fields are handicapped in their support of students.

The other point that I made is that many of them are doing fieldwork. This applies not only to oceanography but to some of the other fields such as geophysics. They are doing fieldwork which prevents them from being supported except by rather roundabout means.

Mr. HECHLER. You mentioned only one university has an undergraduate course in oceanography.

Dr. RILEY. That is true.

Mr. HECHLER. Would you recommend that oceanography be extended as a subject of undergraduate instruction in other universities?

Dr. RILEY. It depends upon what kind of oceanographer you want to produce. For a man who wants to take an undergraduate degree, simply a bachelor's degree, and go into service in, say, fisheries work, or the Hydrographic Office, I think that an undergraduate degree in oceanography is excellent, but if a man wants to go to the top, get his Ph. D., I would be absolutely against it. It would be much better to do his early work in basic disciplines and then specialize in oceanography at the graduate level.

Mr. HECHLER. I appreciate your statement, Dr. Riley. It has been very enlightening.

Mr. KARTH. Doctor, I was a little touched by the examples you gave of the problems which are suffered by those who are doing graduate or postgraduate work in oceanography as much as I generally am in this whole educational field. Is it not true, however, that this problem is pretty germane in all areas of graduate or postgraduate work, whether you are talking about medicine, astronomy, or chemistry?

Dr. RILEY. Yes, sir; it is. Over and above this particular bill, I would plead for better support of graduate students in general.

Mr. KARTH. But this bill and your prepared statement here deal only with oceanography, do they not?

Dr. RILEY. The bill, yes. Our Committee recommendations, yes. Being an oceanographic committee, we were thinking primarily of our own discipline, but I would be terribly disappointed if this were not an entering wedge which would give better conditions for all graduate students.

The CHAIRMAN. In other words, you think it should be broadened to include specialists in the earth sciences generally, rather than limit it to one science like oceanography?

Dr. RILEY. Yes, sir; I do. As I say, these interdisciplinary sciences need it most, but certainly we need better support for all graduate students, regardless of discipline.

Mr. KARTH. Doctor, you say the interdisciplinary sciences. Would you care to enumerate all of those that you have in mind?

Dr. RILEY. Oceanography, meteorology, geophysics, and geochemistry are the main ones in the earth sciences group.

Mr. KARTH. You stated before, I think, in answer to one of Mr. Hechler's questions, that the National Science Foundation does not give special consideration to the discipline problems of oceanography. Is it not true that, irrespective of whether we are talking about oceanography or something else, they cannot give special consideration; that their consideration must be in perspective of the whole, the need and the demand, the use, the importance, et cetera?

Dr. RILEY. That certainly is correct at the present time.

Mr. KARTH. One further question. What did you mean when you said time is running out? Would you care to elaborate on this? I did not quite get the significance of your statement with respect to this question.

Dr. RILEY. I was speaking in particular of the Navy problem. We cannot use our submarines and our antisubmarine defenses efficiently until we know more about the ocean. In other respects I think time is running out, too, with respect to some climatological problems. It is quite evident, for example, that, because of the industrial use of fossil fuels, the carbon dioxide content of the atmosphere is gradually building up. This we can expect to have a sort of general warming effect on the earth as a whole, simply because carbon dioxide blankets the earth against back radiation.

We know that the oceans have warmed up several degrees in the arctic and subarctic regions during the last few years. We know that there is more ice-free water in the Arctic. This is such a complicated problem that we cannot say definitely that this is cause and effect, but it is something that we need to have concern about.

Mr. KARTH. Have there ever been other periods in history when this has been true, where the arctic regions have warmed up several degrees and a century later cooled off?

Dr. RILEY. Yes; there are fluctuations in climate. We do not know for sure at the moment whether this is a direct result of carbon dioxide or just a variation in solar radiation. But what is giving oceanographers nightmares at the moment is the hypothesis that was advanced a few years ago by a distinguished colleague of mine and also a member of this Committee, Dr. Maurice Ewing. Understand, this is just a hypothesis, one of these things that scares us but we do not know whether it is true or not. He claims that if the Arctic Ocean ever warms up to the point where it is ice free, there will be sufficient evaporation to increase the precipitation over the northern part of the continent, and this will send us irreversibly into an ice age again. This is a cold war that will really be a cold war for us.

Mr. KARTH. This is the reverse of what you would expect.

Dr. RILEY. Yes.

The CHAIRMAN. It is a boomerang.

Dr. RILEY. You understand there is a terrific argument about this at the moment. A lot of people think that this would not happen, but it has stimulated a great deal of research on the carbon dioxide content of the air, the interchange of carbon dioxide between the air and the water, as well as a lot of thinking along theoretical lines. I

feel as if in that respect this is a problem we have to solve fairly rapidly. There, again, time is running out on us. If Dr. Ewing is correct, within the next 100 years or so we will be forced at great expense to precipitate the carbon dioxide out of our factory flues.

Mr. KARTH. Of course it is true, is it not, Doctor, if the sun cools off, the earth will cool off correspondingly, eventually? I do not know what year we are talking about. I cannot project my thinking that far into the future.

Dr. RILEY. You are talking about an inevitable event that will come millions or billions of years from now. In the other case we are talking about something which is almost our immediate future and something we can do something about.

Mr. KARTH. In the hypothesis that your colleague propounds, he is not talking about this occurring in the next 100 years.

Dr. RILEY. It would take a long time for it to build up.

Mr. KARTH. He is talking about this thing happening sometime in the distant future.

Dr. RILEY. It would be a matter of slow growth, with the climate gradually worsening.

Mr. KARTH. According to the latest statistics, if we have any, what is the rate of growth of carbon dioxide in the atmosphere?

Dr. RILEY. I am not enough of a geochemist to give you those figures precisely, but it certainly is a distinctly measurable amount.

Mr. KARTH. Enough so that you have grave fears that perhaps something will have to be done about it within the next 100 years? Is that not what you said?

Dr. RILEY. Yes; I think we can expect a change in the climate of one sort or another; perhaps mild, perhaps severe.

The CHAIRMAN. In how many years?

Dr. WILEY. We are beginning to feel the effects already, if there is a casual connection. That, again, we cannot be sure of.

The CHAIRMAN. You do not bring it down to this present heat wave; do you?

Dr. RILEY. No, sir. Really, I am not trying to scare you or to predict something awful, but these are the things that oceanographers have to think about and work on.

Mr. KARTH. Does the Navy agree that we must do considerably more work in oceanography before our submarine methods of warfare will be efficient?

Dr. RILEY. We are wholeheartedly in agreement.

Mr. KARTH. They have made no recommendations along that line to this committee, and that is why I asked the question. They talked about everything else.

Dr. RILEY. The Geophysical Branch of the Office of Naval Research wrote what they call the tenoc plan, 10 years of oceanographic effort, and their proposal within the limits of certain sciences was very much the same as our own committee recommendations. They were with us 100 percent.

Mr. KARTH. To the best of my knowledge, they have not testified here that the submarine warfare they are now entering into is not extremely efficient. In fact, they state it is so efficient that this is the only way, in their opinion, really to fight an intelligent modern war,

such an efficient method of warfare that this is the only intelligent approach to the whole space age theory of nuclear warfare.

Dr. RILEY. They might very well say that and be correct, yet knowing that some of their methods are not nearly so efficient as they ought to be, particularly this problem of detecting other submarines.

Mr. KARTH. Of course, Doctor, we will agree that almost anything that either you or I could think of is not so efficient as it could possibly be, but I suppose the real question is whether or not it is within the realm of possibility.

That is all, Mr. Chairman.

STATEMENT OF HON. GEORGE P. MILLER, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

The CHAIRMAN. We are fortunate this morning in having our colleague, Mr. Miller, who suggested earth sciences as a proper subject for the work of this committee.

Mr. Miller, have you any questions?

Mr. MILLER. When I made that suggestion, Mr. Chairman, I also called your attention to the fact that I am chairman of the Subcommittee on Oceanography of the Merchant Marine and Fisheries Committee, which has already taken this subject under study and will continue to study it. But I came down, rather, to appear as a witness before you, and I take advantage of the short time——

The CHAIRMAN. We are happy to have you either in your capacity as a member or as a witness or otherwise.

Mr. MILLER. I just want to say that I want to commend you for introducing H.R. 6298 and assure you that I am in full support of it because I know, as a result of studies which the Subcommittee on Oceanography of the Committee on Merchant Marine and Fisheries has made, the necessity for getting scientists or young men to enter the field of oceanography.

I am sorry I was not here at the beginning of Dr. Riley's statement, but in glancing over it I notice he uses the word that it is an "interdisciplinary" field, and he goes on to define what these disciplines are. I think Dr. Riley has most likely told you that oceanographers today are drawn from other disciplines. They are drawn from chemistry, physics, or mathematics into this field. We need men very badly in that field.

I say to my friend, Mr. Karth, that the information he seeks, certain data, has been given, some of it in executive session, to the Subcommittee on Oceanography, of which I am a member. It has gone into the field pretty carefully, and plans to go into it much deeper.

We do need men in this field. We need to encourage men to get into these other disciplines, and from there on it will be up to the people interested in oceanography to try to attract them to the field of oceanography along with the other fields of the earth sciences.

I want to tell you that oceanography is only one of these. The others are just as broad and just as important. I know you will go into that very thoroughly.

Some of the oceanographers and other people in these fields perhaps will take exception to what I shall say now and which I said some time ago at a meeting at Lubec, Maine, when the Academy of Sciences Com-

mittee met and we had the privilege of sitting in with them for a day. One of the things we must do is to find some way of increasing the stipend of people in oceanography. It is a very poorly and underpaid profession. The people are in it because they are devoted to it. It is a rigorous field. It is not one in which you come down to a laboratory and get in a round of golf or two. These people must go to sea under most adverse conditions.

In our own field, from our own committee, a bill will be before the House this week in which for the first time we shall try to take the wraps off the Coast and Geodetic Survey, which makes a great contribution in this field, which presently is limited to operations within the coastal waters of the United States unless by contract with the Navy or some other agency it is hired to go beyond the coastal waters. A bill was sent down and introduced by Senator Magnuson in the Senate. I had introduced one in the House, but we picked up the same bill. We hope to get it before the House. It has already passed the Senate. This will take the wraps off a great research agency, one of the oldest and the best which can go into this field. It is concerned with the geodesy of the ocean.

In the field of oceanography, a number of sciences must be merged—the matter of heat transfer in ocean waters, and a part of it meteorology.

If you have the opportunity of going to Woods Hole you will find a very distinguished doctor up there, who has perhaps done as much in this field as anyone else and is a very charming young lady. Incidentally, she appeared some time ago on an interesting television show.

One of the things which must be done is to educate our people in Congress to the necessity for broadening this field along with the other sciences. That is why I am so interested and why I wanted to come here this morning to appear in support of the bill. I support its principle that we get some money to get started and get the people who are so badly needed in this field.

The CHAIRMAN. Thank you very much, Mr. Miller.

I want to suggest, too, to our counsel, the printed hearings of Mr. Miller's committee over in the Merchant Marine and Fisheries Committee should be available. We want to study those so there will be as little overlapping as possible. We do not want to overlap his committee work. There is no need for duplication because we will develop the whole program of earth sciences in this particular committee.

At the next meeting of the committee, which has not yet been set, I should like to have, as Mr. Hechler suggested, copies of the bills on coal mining and oil and gas. We may have some other bills. They should be here, too, because they are part of the earth sciences.

Mr. KARTH. I wonder if our colleague would yield for a question.

Mr. MILLER. Surely.

Mr. KARTH. Mr. Miller, do you favor broadening the aspects of this bill to include all earth sciences?

Mr. MILLER. I certainly would. I am not too familiar with the other earth sciences other than the general knowledge that I have of them. I certainly would broaden it, because here is a field which has been very limited and no proper consideration has been given it. Yet as time goes on we are bringing out things all the more in this field which show it has a very practical effect and will have a practical effect.

Let us take one field of oceanography; those things which have to do with the biology of the ocean. We have taken food out of the oceans since the memory of man runneth not to the contrary, but we have taken it out as a hunter. Can you imagine how we would supply the meat which is necessary in this country if we still depended on the game of the forest, if every time we wanted some meat we took down a gun and went out and shot a deer or killed a rabbit? Yet that still is the way we are taking food out of the ocean.

Mr. KARTH. There are no seasons and limits?

Mr. MILLER. There are, in certain phases, but not for certain types of commercial fish. We have some treaties with other nations which are quite complicated. I could cite one of them. I do not want to take up your time. This country and Canada have entered into a treaty relative to the protection of a certain species of fish. This fish spawns in the waters of the North Pacific. The Japanese got into the picture. We entered into a treaty with the Japanese that they would not fish east of a certain degree longitude. This was fine. We made a mistake. We should have gone further west, but this was agreeable. We then were there trying to protect the species for the two or three countries involved. All of a sudden in this area a number of fishing trawlers of another Pacific nation showed up. The seas are free. We cannot say, "You can't come in here and fish."

Mr. KARTH. I understand. Because of the freedom-of-the-seas concept, this thing does not have regulatory power.

Mr. MILLER. This does not lend itself. Even on some of the banks we read about a fishing trawler in an area where we had never seen trawlers of this country before, and where our own country and Canada had certain agreements. A trawler showed up, you remember, some time ago that cut a number of intercontinental telephone lines. Sooner or later, coming out of this, as I see it, we shall have to put up zones of influence in the sea. Certain fisheries biologists have even talked of raising fish and feeding them as we do other animals to bring them in. Maybe this is something that the future holds. The things that we get from the sea are so great that we cannot afford to overlook any of these things. That is why we need science. Heretofore most of the emphasis has been placed on the biological sciences, I think you would agree, Doctor.

Dr. RILEY. That is certainly true.

Mr. MILLER. Now we have ichthyology, and because of this we know more of that phase of it, but now we must get into other phases of this, and not only this but all of the earth sciences. That is why I suggested to the chairman that I thought he should have a committee on earth sciences. I want to support and assure you I support this bill, H.R. 6298. I do think it should be broadened to include all of the disciplines, because you have got to draw men from other phases of science, not only into this but into the general field of earth sciences.

Mr. HECHLER. I wish to make a brief comment, Mr. Chairman. I would not want the record to indicate that I was opposed to oceanography, Doctor. I merely want to see it put in proper perspective. Nine years ago we established the National Science Foundation. I think it is an indication of some lack of confidence, perhaps, to single out one of their activities at a time when I believe they are competent to put oceanography in its proper perspective. I hope these hearings

will serve to emphasize, both to the National Science Foundation and to the general public, the tremendous importance of oceanography and the critical need for training more people in the field.

I should like to ask consent to have printed as part of the record the complete text of chapter 12 of the report by the Committee on Oceanography of the National Academy of Sciences, which is only 8 pages in length. I believe would be desirable.

The CHAIRMAN. If there is no objection, it is so ordered.

(The information requested is as follows:)

OCEANOGRAPHY 1960–70—MARINE SCIENCES IN THE UNITED STATES, 1958[1]

I. INTRODUCTION

The main purposes of this report are to examine the present status and past history of the growth of basic and applied research in the marine sciences in the United States and to analyze some of the current problems of supporting oceanographic research.

Oceanography is a very young area of activity in the United States. It has developed from a handful of laboratories in 1920 to its present status of about 70 laboratories of various sizes. Part of the story of this growth is shown in table 1. The total number of laboratories doubled in the postwar years and has increased nearly tenfold since 1920. The total financial support and personnel has also increased, for most of the existing institutions have increased their staffs and new laboratories have been established.

TABLE 1.—*Number of marine laboratories in the United States and territorial possessions, listed according to sponsoring agency and period when founded*

	Before 1920	1921–30	1931–45	1946–50	1951–58	Total
State	0	2	1	5	1	9
Federal	2	2	8	7	7	26
University	4	3	7	11	5	30
Other[1]	2	2	0	1	0	5
Total	8	9	16	24	13	70

[1] Mainly corporations funded by private contributions or by endowments provided by foundations.

The problems of acquiring a first-rate staff in a competitive market, of financing their research, and of getting and maintaining additional ship and shore facilities have been severe. They have led in some cases to difficult and precarious financing of oceanographic laboratories.

Some of the data used in this discussion came from the "Directory of Hydrobiological Laboratories and Personnel in North America" edited by Robert W. Hiatt and published in 1954 under the auspices of the Advisory Committee on Hydrobiology to the Office of Naval Research. For present purposes the Committee on Oceanography found it necessary to bring this information up to date. Accordingly, in the spring of 1958 a questionnaire was sent to existing marine laboratories in the United States asking for detailed information concerning their programs, financial support, staffs, facilities, and future capabilities. This report summarizes the responses received from 60 laboratories.

Each laboratory was asked to describe its present program and to estimate the percentage of the total laboratory program that was devoted to oceanography. Oceanography was defined as being "* * * primarily concerned with describing and understanding the oceans: Its surfaces, estuaries, shoreline, and deeps." The intended application of this knowledge to a particular practical problem, such as underwater acoustics or fisheries population studies, need not, it was emphasized, rule out this definition of oceanography. The responses to this first question are not summarized here. However, the descriptive answers

[1] A report by the Committee on Oceanography of the National Academy of Sciences—National Research Council.

to this question were used to verify or modify the estimated percentage of each laboratory's program which the directors estimated to be devoted to marine sciences.

II. FINANCIAL SUPPORT

Each laboratory furnished information on the amounts and sources of financial support for the fiscal year 1958. The totals are summarized in table 2. An attempt was made to classify the laboratories into logical groups according to their primary function and size. It is helpful to divide them into two size categories according to whether their budgets are greater or less than $300,000. In almost all cases this criterion separated laboratories capable of operating in the deep ocean from those which specialize in investigations of inshore environments. They were also divided into university, Navy, State fishery, or Federal fishery laboratories. A few nonuniversity laboratories such as the Woods Hole Oceanographic Institution and the Bermuda Biological Station were included in the university classification because of essentially similar research functions. Three other laboratories which could not be put readily into any of these groups were not considered in the comparisons that follow.

TABLE 2.—*Sources of financial support in various kinds of oceanographic laboratories, fiscal year 1958*

[Dollars in thousands]

	Large university	Small university	Large fishery	Small fishery	Navy	Total
Number of laboratories	6	19	6	24	5	60
U.S. Government:						
Bureau of Commercial Fisheries	$248	$526	$2,895	$1,617	----------	$5,286
Office of Naval Research	3,598	379	35	----------	----------	4,012
National Science Foundation	1,277	130	20	9	----------	1,436
Atomic Energy Commission	196	149	----------	325	----------	670
Other	983	1	----------	213	[1] $4,808	6,005
State funds	581	567	36	594	----------	1,778
Total State and Federal funds	6,883	1,752	2,986	2,758	4,808	19,187
Endowments and grants	1,001	360	----------	16	----------	1,377
Other funds	2,281	318	353	110	----------	3,062
Total	10,165	2,430	3,339	2,884	4,808	23,626

[1] Does not include ship operating costs. The oceanographic work at 3 Navy-operated laboratories and 2 laboratories operated under contract by a single Navy agency is included in this category.

The contributions to marine research in industrial laboratories have not been included in this survey. Although their participation in geophysical exploration of offshore and Continental Shelf areas is large, the results of this work are not commonly made public. Some grants and contracts are given to marine laboratories by various industries. These funds are included.

Some additional comments may be made about the contributions from various sources of support. Only two laboratories reported that combined endowments and private grants provided more than half of their total support. Both of these were small, private laboratories. State funds were the sole source of support for four laboratories and the major support of seven others. Twenty-two laboratories received almost all of their support from the Bureau of Commercial Fisheries, and five were financed solely by Navy funds. Six laboratories reported that they received more funds from the Office of Naval Research than any other source. Federal and State funds totaled 70 percent of the university budgets. With minor exceptions, private universities were as dependent on Government funds as the State universities.

III. PERSONNEL ENGAGED IN OCEANOGRAPHIC WORK

Data on laboratory staffs are compiled in table 3. In addition to listing the various categories of staff members, the average cost of supporting the staff is tabulated in items 12 through 15. The questionnaire also requested information on visiting scientists computed on a man-year basis. These totaled 61 Ph. D.'s, 41 with the master's degree or equivalent, 242 summer students, and 36

visitors in other categories. It was estimated that 35 percent of the scientific output of the visitors could be considered oceanographic, as contrasted with 89 percent of the work of permanent staffs.

TABLE 3.—*Summary of budget and personnel data from 5 groups of laboratories*

[Dollars in thousands]

	Large university	Small university	Large fishery	Small fishery	Navy	Total
1. Number of laboratories	6	19	6	24	5	60
2. Total budgets	$10,165	$2,430	$3,339	$2,884	$4,808	$23,626
3. Average	$1,700	$128	$556	$120	$960	$394
4. Total Ph. D.'s	219	79	35	49	47	429
5. Average	37	4	6	2	9	7
6. Total master's plus Ph. D.'s	324	124	92	120	124	784
7. Average	55	7	15	5	25	13
8. Total scientific staff	598	228	201	198	323	1,548
9. Average	100	12	34	8	65	26
10. Total staff	1,250	285	298	314	517	2,664
11. Average	208	15	50	13	103	44
12. Cost per Ph. D.	$46	$32	$93	$60	$107	$56
13. Cost per Ph. D. plus master	$31	$18	$37	$24	$39	$30
14. Cost per scientific staff member	$17	$11	$16	$15	$15	$15
15. Cost per employee	$8	$8	$11	$9	$9	$9

A large share of the total number of oceanographers are working at the few large oceanographic institutions. If we consider how many of the largest laboratories one must count in order to account for over half of the personnel in each of several groups, we have:

Groups	*Number of laboratories*
Ph. D.'s	4
Master's degrees	9
Junior scientists and technicians	5
Support staff (secretarial, assistants, ships crews, etc.)	2
Total, all personnel	2

Each of the four larger institutions have extensive open-ocean programs requiring ships and a strong support staff as well as a large number of Ph. D.'s. The smaller laboratories are relatively weak in numbers of support staff members.

IV. DISCUSSION

Financial problems

Among the university-sponsored organizations, only the large ones have been able to maintain an extensive blue-water operation and large departments in specialized categories such as physical oceanography and geochemistry. In order to support their large ships and technical staffs, most of these laboratories have found it necessary from time to time to conduct relatively large applied research programs for the Government. In some cases such work has necessitated sacrificing more basic research projects. In others, the stimulation provided by applied problems has been helpful. However, laboratories should not have to undertake large applied projects primarily as a means of solving financial problems.

The small university laboratories represent two somewhat different categories. Some are summer seaside laboratories with major emphasis on teaching and marine biological investigations. Others are year-round oceanographic operations in estuarine and coastal waters. There are some intergradations. On the average, only 38 percent of the support of the smaller university laboratories is obtained through Federal funds. They depend mainly on general university funds, derived either from private or State sources. They are less dependent on specific research grants than the larger organizations and hence have maintained a larger measure of financial stability. However, this has been accomplished only by severe limitation of the scope of their activities.

Each laboratory has its own particular problems, but some general patterns are discernible. The large laboratories with heavy Federal support need financial stability and predictability to rescue them from their present hand-to-mouth existence on short-term contracts. The insecurity of this existence is a constant worry to administration and staff alike; it interferes with long-range planning

and it sometimes results in taking on routine survey tasks that are not the proper work of a research organization and contribute little to the laboratory except as a financial stopgap. They desperately need ship replacements and additional shore facilities. They need the kind of general institutional support that will permit them to maintain their salary scale at the current market value and provide reasonable stability to their operations.

The small laboratories also need ship and shore facilities but generally not so desperately. Often their chief material need is for modern scientific equipment, and in this respect their work tends to be limited in scope because they cannot hope to acquire the large stock of expensive instruments that are more or less standard equipment in larger organizations. However, their most pressing need is for growth and diversification of their staffs. The small laboratories consist almost exclusively of biologists and biological oceanographers. They have learned a few techniques of physical and chemical oceanography to supply background for their biological studies, but specialists in these subjects are essential both for teaching and for solving the particularly difficult problems of coastal circulation and nutrient cycles.

We find ourselves looking at the two faces of the same coin. The small laboratory has to grow in order to solve its problems effectively and having done so, it finds a whole new set of problems waiting for it. Perhaps some laboratories have overexpanded, but it is clear that gradual expansion is necessary in order to meet the increasingly exacting requirements of modern oceanography.

Government laboratories

The federally operated laboratories, both Navy and fishery, also have serious financial problems. They have a more stable situation than the large university laboratories, but their budgets fluctuate unpredictably. It is commonly considered that their primary function is to be service organizations conducting routine surveys and applied research. Some basic research is undertaken, but when budgets are curtailed the basic research is the first to suffer. This is one reason why Federal laboratories do not attract large numbers of highly trained scientists. Table 3 shows a disproportionately large ratio of total scientific staff to Ph. D.'s in these laboratories as compared with the universities. It is not a healthy situation, and it probably cannot be corrected until legislators become aware that it is a good investment to maintain a stable, long-term program of basic research in Federal laboratories.

Comparison of laboratories

One way of comparing the problems and organization of various laboratories is to examine the cost of the operation per staff member, as shown in table 3. The size of the staff is a crude measurement of the research product, but it is a practical way of looking at the matter because the management has to think in terms of cost per unit of accomplishment.

In seaside laboratories of a seasonal nature, which pay only the summer salaries of their staff, the cost per staff member is usually about $2,000 to $5,000. It is seldom larger unless the laboratory supports a considerable number of visiting investigators who are not listed as staff members.

At the opposite extreme are the large, deepwater operations that cost $50,000, more or less, per senior staff member. This reflects both the high cost of operating large ships and the relatively large number of junior scientists and nonscientific staff members at these institutions.

The cost per scientist is distinctly lower in the small university laboratories than in any other group. In part this is due to the lower cost of coastwise operations, but it also is to some extent an indication of inadequate equipment and supporting staff. The number of technicians and nonscientific staff members is undoubtedly too low for an efficient use of trained scientists.

The small fishery laboratories have field programs more or less similar to those of the small universities, so that the financial problems of these two groups are somewhat comparable. The very high cost of $60,000 per Ph. D. in the fishery laboratories simply reflects the very small number of people in this category. More reasonable figures for comparative purposes are the cost of $24,000 per master or Ph. D. and $15,000 per scientific staff member. Each of these is $4,000 more than the corresponding figures for university laboratories, and it is suspected that they are more realistic for this kind of operation.

Total support

While making this study, we tried to estimate that portion of the total budgets of the laboratories that is actually spent on oceanographic research. Our best

estimate is that this is about 63 percent of the total. This figure contains subjective elements, as indicated earlier. However, it should also be recognized that oceanography is directly or indirectly benefited by research in many institutions that are not included in the present tabulation. This includes work in basic disciplines and also in related interdisciplinary fields such as geophysics, geochemistry, and meteorology. The contribution from such sources is probably about equal to the missing 27 percent in the subjective estimate mentioned above. The figures included in this report establish the amount that oceanographic institutions spend on activities that they consider worth supporting, and this, after all, is the only practical way to look at the matter.

Growth of oceanography

Finally, it is of considerable interest to determine the rate of growth of oceanography in the immediate past as an indication of what might be expected in the future. Information was obtained from Hiatt's "Directory of Hydrobiological Laboratories," which was compiled during the fiscal year 1953. As an additional check an abstract of the comparative information for 1953 and 1958 was sent to the directors of 28 of the laboratories for which data from both years were available. Each director was asked to confirm or change the data to represent as nearly as possible the real change over this 5-year period.

The laboratories in question listed a total expenditure of about $8 million in 1953 and $14 million in 1958—an increase of 76 percent. The question immediately arises as to how much of this increase represents real growth and how much is simply inflation. Some data on the 1953–58 inflationary factor can be obtained by examining research proposals in the files of the Office of Naval Research. They indicate that the increase in salaries for various grades of staff members at various laboratories ranged from 20 to 80 percent during this time interval, with the majority of percent increases for the largest number of staff members ranging between 30 and 40 percent. A similar review of ship operating costs showed an increase of between 40 and 50 percent. The study further revealed that the funds spent by private research laboratories are devoted approximately one-third to ship operating costs; one-third to salaries; and one-third to equipment, travel, overhead, and other items. In the latter group, inflation has been slightly less extreme than in the first two. Nevertheless, the analysis suggests an inflationary factor of at least 30 percent and possibly more, and the real growth might therefore be of the order of 30 to 45 percent in 5 years. This is probably a slower rate of growth than that of the early postwar years when the formation of new laboratories (table 1) occurred more rapidly than in any other period before or since. The present rate of growth is more in keeping with the ability of the science to produce new oceanographers and to supply the ship and shore facilities that they require. An increase of 30 to 45 percent in 5 years is equivalent to 70 to 110 percent in 10 years. The recommendation for doubling of oceanographic research in the next 10 years contained in the first chapter of this report, therefore, seems well within our capabilities and in line with a moderate acceleration of our present rate of growth.

The CHAIRMAN. Could we have available copies of your hearings?

Mr. MILLER. I do not know that we print the hearings of our subcommittee. We are not as wealthy as this committee, so we have held them up. I am certain that we can see that you get them in galley form, anyway.

The CHAIRMAN. Or, if you would let us have copies of your stenographic notes, we would go through them, and that part which is relevant, of course, with the consent of your committee, we could use in the record of this committee, and therefore avoid duplication. We would like you to remain, Mr. Miller.

Mr. MILLER. I have some other business, much as I would like to remain.

The CHAIRMAN. We would be happy to have you anytime.

Mr. MILLER. I shall try to come when I can. I did want to get on record in favor of your bill.

The CHAIRMAN. We were glad to have you here and to hear your testimony.

Mr. CHENOWETH. Doctor, do I understand the situation is such that you have a very promising prospect for oceanography, but that there are no funds available to help you in these studies at all? Is that our situation today? You say there is a shortage of prospects, and you are looking for them, and you have no trouble placing them. Do I understand, with all of this money we are spending, with all the foundation and Government assistance today, there is nothing for a young man of that type?

Dr. RILEY. We do have sources of funds. We have private funds. We have fellowships for our few top men that we can get from the universities or from Government sources of one sort or another. We have a certain number of research assistantships that we can get from Federal grants.

The real point is, first, that it is impossible to support an average man on fellowship money. A hardship case who has heavy family responsibilities, in order to earn enough money through a research assistantship to support his family, is so heavily loaded with work that it takes a horribly long time for him to get through school.

Mr. CHENOWETH. You mentioned one case of that type in which it took 11 years to go through.

Dr. RILEY. Yes.

Mr. CHENOWETH. But you do have funds for promising prospects in this field with which you can assist them now?

Dr. RILEY. Yes. We have funds for most of our men. It is largely the special cases that we find it difficult to support—the people in strictly oceanographic graduate departments who are prevented from teaching assistantships because there are no undergraduates to teach, the people who have to go off and do fieldwork someplace and are thereby not able to carry an assistantship in the university, the hardship cases who really need more money than we can supply.

Mr. CHENOWETH. How does the ratio of these hardship cases compare with the others?

Dr. RILEY. It is a rather small proportion.

Mr. CHENOWETH. Perhaps you have already covered this one further question which I have, Doctor. What is our relative standing with the Russians in this field of oceanography at this time? Have they paid special attention to this field? Would you say that we have neglected it, relatively speaking? What is our relative interest and capacity at this time?

Dr. RILEY. They are putting much more money into oceanography right now than we are. They are providing more adequate support for students. I would not say their oceanography is better than ours. It is better in certain fields and poorer in others. You cannot make a broad statement on it.

Mr. CHENOWETH. Have you had some exchange of professors between the two countries? Have some of you been over to Russia and seen what they are doing there?

Dr. RILEY. No, sir; I have not. I am sorry to say that I am more ignorant than I would like to be of what they are doing. I have to depend on an occasional visitor from Russia or upon the Russian literature as to what they are doing.

Mr. CHENOWETH. In all the geophysical program we have had, there has been no exchange of ideas or professors in the area of oceanography?

Dr. RILEY. There have been short-term visits back and forth; yes.

Mr. CHENOWETH. What have our people reported when they came back?

Dr. RILEY. They report that it is spotty. Some of it is very good. Some of it is not. I would say our earth sciences programs are the same way.

Mr. CHENOWETH. You would say, then, we are holding our own or perhaps a little better, so far as the Russians are concerned, in this field?

Dr. RILEY. For the time being, yes, but the amount of money they are pouring into the field will tell eventually.

Mr. CHENOWETH. How is this money being spent?

Dr. RILEY. It is being spent to support students and professors at a relatively higher wage level than we have in this country. It is being used to provide excellent equipment, perhaps better equipment in some respects than we want. I do not think we want 6,000-ton oceanographic vessels in this country. We operate in different ways from them. I do not think we want that, but certainly we do need a considerable number of new oceanographic vessels.

Mr. CHENOWETH. The fact that they are spending this large amount of money does not necessarily mean that they are superior to us in this field, does it?

Dr. RILEY. Intellectually they are not superior to us, I would say. After all, scientifically speaking, they are a young country. They are moving ahead faster than we are, but in many respects they have not caught up with us yet.

Mr. CHENOWETH. They were a long way back to start with, were they not?

Dr. RILEY. Yes.

Mr. CHENOWETH. But they are coming faster now, you say.

Dr. RILEY. Yes.

Mr. CHENOWETH. I think that is all, Mr. Chairman.

The CHAIRMAN. Thank you very much, Doctor.

STATEMENT OF HARRY C. KELLY, ASSISTANT DIRECTOR, DIVISION OF SCIENTIFIC PERSONNEL AND EDUCATION, NATIONAL SCIENCE FOUNDATION, ACCOMPANIED BY BOWEN C. DEES, DEPUTY ASSISTANT DIRECTOR, DIVISION OF SCIENTIFIC PERSONNEL AND EDUCATION; ROY E. HANSON, ASSISTANT PROGRAM DIRECTOR, EARTH SCIENCES PROGRAM; AND CHARLES B. RUTTENBERG, ASSISTANT GENERAL COUNSEL

The CHAIRMAN. We have one more witness this morning, and that is Dr. Harry C. Kelly, Assistant Director for Scientific Personnel and Education of the National Science Foundation.

Will you have a seat there, Dr. Kelly? If you will give us some of your background, we would appreciate it.

Dr. KELLY. May I also invite several other members of the Foundation staff up here with me?

The CHAIRMAN. We would be happy to have them up here.

Dr. KELLY. Dr. Bowen Dees, who is Deputy Assistant Director for Scientific Personnel and Education; Dr. Roy E. Hanson, who is Assistant Program Director of the Earth Sciences Program of the Foundation, who got his Ph. D. in seismology at St. Louis University; and Mr. Charles B. Ruttenberg, Assistant General Counsel of the Foundation. I believe you remember him.

The CHAIRMAN We are happy to have you gentlemen here.

Are you Director of the Earth Sciences Division of the Science Foundation?

Dr. KELLY. No, sir. I am in charge of the Division of Scientific Personnel and Education. This includes education in all of the fields of science, engineering, and technology. Dr. Hanson is in the program of research support in the field of the earth sciences. His work is specifically directed to the earth sciences. Ours is directed to all fields.

The CHAIRMAN. You have a prepared statement, Doctor?

Dr. KELLY. Yes, sir; I have.

The CHAIRMAN. We shall be happy to hear it.

Dr. KELLY. We are very much pleased at the opportunity of coming back to discuss with you again the problems of education in the sciences; this time to emphasize our attitude and programs directed toward the earth sciences and other special categories.

I would like to emphasize, as Mr. Hechler has done, that we, too, recognize the great importance of training and research in oceanography, and that this is an important need and intensive efforts should be made to fulfill this need. However, we would like to point out that there are already in existence several major programs which should be used more fully than they have been so far in meeting the goals which underlie H.R. 6298. The National Science Foundation itself carries out a number of activities which should be much more influential in this field as we develop, in cooperation with oceanographers, more applicable projects in our present programs.

First, I should like to review the range of our NSF programs that deal directly with education in the sciences. There are today many fellowships available to individuals who are interested in this field of study. The National Science Foundation maintains two predoctoral fellowship programs, both of which support individuals who wish to study or work in the field of oceanography. If we are successful in encouraging a larger number of competent individuals to apply to us for fellowships in oceanography, there will be more awards in this field. We believe the problem is not so much that of making more fellowships available for students who wish to pursue work in oceanography or the earth sciences; it is more a question of stimulating students to take an interest in becoming earth scientists or oceanographers.

As was pointed out by Dr. Riley, oceanography and the earth sciences, unlike the standard disciplines of physics, chemistry, and mathematics, is a derived science. It is dependent upon these other, more basic, fields. As Dr. Riley pointed out, there is only one university in the United States giving a bachelor's degree in oceanography. Perhaps some consideration should be given to methods of encouraging other universities to develop programs.

One of our newly developing programs will prove particularly useful in this connection. For each of the last 3 years we have supported a few experimental efforts to supply highly specialized training opportunities to augment the competence of already well-trained scientists and engineers. For example, we have supported a training program extending over several months to enable professors of mathematics from a number of institutions to learn how to use and, more important, how to teach the use of advanced electronic computers. We call such projects special field institutes. We can all agree that the earth sciences might well be referred to as a special field, and in fact we have supported a special field institute centered on oceanographic problems this past summer at the Woods Hole Oceanographic Institution. This program should be even more useful in the future.

As an illustration, we would be glad to consider a proposal from an outstanding oceanographic institution to plan a course of study which might involve a number of scientists already well trained in one or more of the basic fields important to oceanography. At this special field institute these scientists could obtain specific and well-conceived instruction and experience in connection with the special problems encountered in research in oceanography. Such a special field institute could within a relatively short while make it possible for individuals already having Ph. D.'s in such fields as physics, chemistry, and the like to work confidently and expertly on oceanographic problems and perhaps even start training other members of new departments of oceanography.

Clearly, the important thing in connection with improving our research output in the general area of oceanography is to provide training for individuals of high ability who have a real sense of dedication to research in this field. In general, able students decide which field of study they wish to pursue in graduate school at least 1 or 2 years before they finish college. Since courses at the undergraduate level are not generally offered in derived fields such as oceanography, it is necessary to find special ways of challenging and exciting the interest of the typical undergraduate. Otherwise, students will not be given an opportunity to develop a conception of what a career in oceanography would be like prior to the time when they have made a career commitment to some other field of science.

It is therefore essential that mechanisms be provided which will reach down into the college, and perhaps even into high school, to present to able students the challenges and the rewards of research and teaching careers in the earth sciences.

There are four specific programs of the National Science Foundation that immediately come to mind in this connection. One of these is the program which we refer to as the undergraduate research participation program. In this activity the National Science Foundation provides grants which enable the participating universities to offer special research-oriented training opportunities for undergraduates during the summer months, and, in some cases, throughout the academic year. These training programs may be carried out on a university campus, at a field station, or even aboard an oceanographic vessel. They are centered on research opportunities which make it possible for the undergraduates to work in close contact with scientists who are doing significant research. As it applies to the problem of increasing the number of students studying oceanography, this program

offers the possibility of presenting to highly selected undergraduate students some of the specific techniques of research in the earth sciences.

It is certain that this type of program can have the effect of exciting the interest of undergraduate students and turning their minds in the direction of graduate study in oceanography or the earth sciences generally.

At a lower academic level, the National Science Foundation program of secondary school student training programs provides a variety of mechanisms by which carefully selected high school students can be shown the challenges of a particular scientific field and be given an explanation of the type of work that is actually carried out.

College teachers in the various fields relevant to oceanography need to know more about oceanography and the earth sciences so they can broaden the outlook of their students. Summer institutes and conferences in oceanography designed to meet the needs of these college teachers could become an important phase of the effect to give oceanography a fuller degree of recognition and college students a better idea of the rewards of careers in this field.

The last of our programs in science education I shall mention is our program of visiting scientists. This program makes it possible for outstanding scientists to visit college campuses and, to a limited extent, high schools, also, throughout the country, where they present to the students some of the latest findings in the various scientific fields.

Thus far the Foundation has supported a number of fields and experience has shown that this program is a powerful mechanism for stimulating undergraduate students to take an interest in graduate study.

The programs I have been discussing so far are programs classified under our heading "Education in the Sciences." Our second set of suggestions relates to the research-supporting operations of the National Science Foundation. These are also of major importance in connection with the entire problem. The Foundation research grants provide funds to enable individuals already trained in oceanography to carry out research in this field and related areas of science.

Grants made in support of oceanography or the earth sciences typically provide funds for the support of research assistants. The term "research assistants" is used to mean graduate students who are working on specific research projects. In many instances these students work on their dissertation problems in connection with a research grant which has been supported through the basic research program. With the additional funds being made available to the Foundation for the support of basic research, more support can go into projects related to the earth sciences and, therefore, additional support will be provided for the training of graduate students in the earth sciences, including oceanography.

You are aware of the fact that, despite the great potentialities of oceanography for contributing toward both scientific and practical objectives, the study of the seas is one of the most important underdeveloped areas of science today. One of the reasons why we have so little knowledge of the oceans and their physical and biological characteristics is that there is a critical shortage of modern long-range

oceanographic research vessels. This year, for the first time, the Foundation will be able to provide funds for the acquisition of such a vessel. The total cost of this ship will be approximately $2 million. The Foundation is currently giving serious consideration to the need for an additional oceanographic vessel of larger size.

The third point I should like to emphasize is the fact that there are other Federal agencies also which are in a position to support programs to help build up our research potential in the field of oceanography. The Office of Naval Research and the National Institutes of Health, for example, can provide certain kinds of needed support through their research programs. Moreover, the National Defense Education Act provides in title IV for some 1,500 national defense fellowships each year from academic year 1959–60 through the academic year 1961–62. Proposals from educational institutions to the Department of Health, Education, and Welfare for the establishment of new programs or for the expansion of existing graduate programs in this field would be given serious consideration, I am sure, by the Health, Education, and Welfare group.

We believe that the key problem which we face in this whole area is that of assuring excellence in instruction in science at all educational levels. When we have come close to achieving this goal we will have less difficulty in getting enough high-quality students to take an interest in careers in science. Therefore, we need to find ways of encouraging additional students to become interested in science, and then we must not only assure high-quality instruction for them but we should also find ways of helping them to get information about careers.

The Foundation has been concerned since the beginning of its existence about determining the relative priorities of needs in various special fields of science. The Foundation has given consideration, for example, to the programs of research in problems unique to the Antarctic; it has considered as a problem area which needs special consideration the area of astronomy; and similarly, more recently, it has considered the special needs presented by the field of meteorology. In addition, there is a severe shortage of teachers of engineering, and special consideration also must be given to the problem of how we can increase the number of teachers of engineering in our universities.

When matters like this come up for discussion, it is soon seen that it is virtually impossible to draw up a meaningful table of priorities. What is currently the most important field of science? How does one determine which area needs help most urgently?

We are keenly aware of the importance of oceanography and all of the earth sciences, but we are also aware of the importance of solid-state physics, plasma physics, research on missile propulsion or in any one of the many other fields. Experience demonstrates that it would be unwise to single out any one area of research and say that it is so much more important than others that it demands unusual and crash-program consideration. Hence the identification of certain limited fields of science so that they may be given special attention and special treatment is not the wise way to improve our scientific potential. Rather, we should move in the direction of providing adequate resources to assure a continuous increase in the

number of young people obtaining good basic training in the sciences at the high school and college levels. These students would then be in a position to undertake graduate training in a variety of fields—not just the few that are of special importance today, but also those fields which are certain to arise and to be of crucial importance within the next 5 or 10 years.

Because science is creative, new fields of knowledge will be developed requiring more scientific personnel and research facilities. At least for the basic sciences, we believe it unwise to overplan and overdirect research and educational activities. Scientific advances are creations of men, well trained and creative, who have a strong motivation to understand the mysteries of nature. Rather than developing a kind of "Maginot line" of technology, we believe we must respond to the curiosity and competence of creative scientists, for it is these scientists who are to create the new fields of technology.

To summarize, we recognize that there is a growing and recognizable need for more competent oceanographers. However, we recognize also that there are a number of fields in which we have a shortage of highly competent, highly trained scientists, and our greatest effort should be to alleviate the overall problem. We believe that this can be done by interesting more of our able young people in the intellectual challenges and career opportunities in all fields of science and technology. Our approach to this problem was described to you in our previous appearance before your committee.

We also believe that we should, along with other agencies of the Federal Government, continue to study methods of support of special areas of science and technology. We will continue to make a special effort to stimulate the scientific community in these special areas by encouraging both students and scientists to apply for fellowship and research grants for support from the Foundation, and by encouraging greater participation in other programs of the Foundation, including those of special field institutes, visiting scientist programs for both college and high school students, summer training programs in science and engineering, and the like.

In view of the considerations I have outlined, Mr. Chairman, we do not recommend passage of H.R. 6298, and we stand ready to try to answer any questions.

(Dr. Kelly's prepared statement follows:)

TESTIMONY OF HARRY C. KELLY, ASSISTANT DIRECTOR FOR SCIENTIFIC PERSONNEL AND EDUCATION

Mr. Chairman, it is a pleasure to have the opportunity of appearing before your committee to discuss the things that should be done to assure adequate training and research in the important field of oceanography.

I am Harry C. Kelly, Assistant Director for Scientific Personnel and Education of the National Science Foundation. The Director of the Foundation, Dr. Waterman, has already supplied your committee with some comments with respect to H.R. 6298, but it may be useful if we present some additional information in further explanation of our views regarding the subjects covered in H.R. 6298.

I would like to emphasize at the outset that the Foundation considers training and research in oceanography an important need, and intensive efforts should be made to rectify the inadequate attention paid to this field of research in the past. However, it is significant to note that there are already in existence several major programs which can be used more fully than they have been so far in meeting the goals which underlie H.R. 6298. The National Science Foun-

dation itself carries out a number of activities which should be much more influential in this field as we develop, in cooperation with oceanographers, more applicable projects in our present programs.

First, I should like to review the range of NSF programs that deal directly with education in the sciences. H.R. 6298 calls for special fellowships to be awarded in the field of oceanography. However, there are today many fellowships available to individuals who are interested in this field of study. The National Science Foundation maintains two predoctoral fellowship programs, both of which support individuals who wish to study or work in the field of oceanography. If we are successful in encouraging a large number of competent individuals to apply to us for fellowships in oceanography, there will be more awards made in this field. Hence the problem is not so much a problem of making fellowships available for students who wish to pursue graduate studies in oceanography; it is more a question of stimulating students to take an interest in becoming oceanographers.

Oceanography, unlike the standard disciplines of physics, chemistry, mathematics, zoology, and the like, is considered to be a derived science: it is dependent upon these other, more basic, fields. Only one university in the country offers a bachelor's degree in oceanography. As a rule, oceanographers are drawn into the field after they have completed a substantial amount of training in one or more of the basic sciences. This means that it would be possible in many instances for individuals who have been trained to a substantial level of competence in physics, let us say, to obtain additional and specialized training which would enable them to do work at a high level in oceanography without having to spend a great deal of time in the study of oceanography as a formal discipline.

One of our newly developing programs will prove particularly useful in this connection. For each of the last 3 years we have supported a few experimental efforts to supply highly specialized training opportunities to augment in important ways the competence of already well-trained scientists and engineers. For example, we have supported a training program extending over several months to enable professors of mathematics from a number of institutions to learn how to use—and, more important, how to teach the use of—advanced electronic computers. We call such projects special field institutes. We all can agree that oceanography might well be referred to as a special field and, in fact, we have supported a special field institute centered on oceanographic problems this past summer at the Woods Hole Oceanographic Institution. This program can be even more useful in the future, however.

As an illustration, we would be glad to consider a proposal from an outstanding oceanographic institution to plan a course of study which might involve a number of scientists already well trained in one or more of the basic fields important to oceanography. At this special field institute these scientists could obtain specific and well-conceived instruction and experience in connection with the special problems encountered in research in oceanography. Such a special field institute, although it would not produce individuals having Ph. D.'s in oceanography, could within a relatively short while make it possible for individuals already having Ph. D.'s in such fields as physics, chemistry, geology, and biology to work confidently and expertly on oceanographic problems.

Clearly, the important thing in connection with improving our research output in the general area of oceanography is to provide training for individuals of high ability who have a real sense of dedication to research in this field. In general, able students decide which field of study they wish to pursue in graduate school at least 1 or 2 years before they finish college. Since courses at the undergraduate level are not generally offered in derived fields such as oceanography, it is necessary to find special ways of challenging and exciting the interest of the typical undergraduate; otherwise, students are not given an opportunity to develop a conception of what a career in oceanography would be like prior to the time when they have made a career commitment to some other field of science. It is therefore essential that mechanisms be provided that will reach down into the college (and conceivably into the high school) to present to able students the challenges and the rewards of research and teaching careers in oceanography.

There are four specific programs of the National Science Foundation that immediately come to mind in this connection. One of these is the program that we refer to as the undergraduate research participation program. In this activity the National Science Foundation provides grants which enable the participating universities to offer special research-oriented training opportunities

for undergraduates during the summer months and (in some cases) throughout the academic year. These training programs may be carried out on a university campus, at a field station, or (conceivably) aboard an oceanographic vessel.

They are centered on research opportunities which make it possible for the undergraduates to work in close contact with scientists who are doing significant research. As it applies to the problem of increasing the number of students studying oceanography, this program offers the possibility of presenting to highly selected undergraduate students some of the specific techniques of research in oceanography. It is certain that this type of program can have the effect of exciting the interest of undergraduate students and turning their minds in the direction of graduate study in oceanography and, therefore, careers in this field. At a lower academic level, the National Science Foundation program of secondary school student training programs provides a variety of mechanisms by means of which carefully selected high school students can be shown the challenges of a particular scientific field and be given an explanation of the type of work that is actually carried out in that field. This summer, for example, the American Meteorological Society has sponsored a program along exactly these lines in an effort to arouse interest on the part of a selected group of high school students in possible careers in meteorology. Similar programs in oceanography would undoubtedly arouse the interest of a number of high school students, and the Foundation would be glad to consider proposals for establishing and carrying out such programs.

College teachers in the various fields relevant to oceanography need to know more about oceanography so that they can broaden the outlook of their students. Summer institutes and conferences in oceanography, designed to meet the needs of these college teachers, could become an important phase of the effort to give oceanography a fuller degree of recognition, and college students a better idea of the rewards of careers in the field.

The last of the NSF science education activities I shall mention is our program of visiting scientists. This program makes it possible for outstanding scientists to visit college campuses—and, to a limited extent, high schools, also—throughout the country, where they present to the students some of the latest findings in the visiting scientists' fields. Thus far the Foundation has supported programs in a number of fields, and experience has shown that this program is a powerful mechanism for stimulating undergraduate students to take an interest in graduate study and to think in terms of graduate study in the field of the visiting scientist. As a mechanism for bringing additional students into oceanography, therefore, this is a particularly useful possibility, and one which we shall encourage oceanographers to make use of in the near future.

The programs I have been discussing are all classified under the "Education in the sciences" heading. My second set of suggestions relates to the research-supporting operations of the National Science Foundation. These are also of major importance in connection with this entire problem. NSF research grants provide funds to enable individuals already trained in oceanography to carry out research in this field and in related areas of science. Grants made in support of oceanography (as in other fields) typically provide funds for the support of research assistants. The term "research assistants" is used to mean graduate students who are working on specific research projects. In many instances these students work on their dissertation problems in connection with a research grant which has been supported through the NSF basic research program. With the additional funds being made available to the Foundation for the support of basic research, more support will go into projects related to oceanography and, therefore, additional support will be provided for the training of graduate students in oceanography.

You are well aware of the fact that, despite the great potentialities of oceanography for contributing toward both scientific and practical objectives, the study of the seas is one of the most underdeveloped areas of science today. One of the reasons why we have so little knowledge of the oceans and their physical and biological characteristics is that there is a critical shortage of modern long-range oceanographic research vessels. There simply has not been enough money available from any source to provide these relatively expensive ships. This year, for the first time, the Foundation will be able to provide funds for the acquisition of such a vessel; the total cost of this ship will be approximately $2 million. The Foundation is currently giving serious consideration to the need for an additional oceanographic vessel of larger size.

The third major point I should like to emphasize is the fact that there are other Federal agencies also which are in a position to support programs to help build up our research potential in the field of oceanography. The Office of Naval Research and the National Institutes of Health, for example, can provide certain kinds of needed support through their research-support programs. Moreover, the National Defense Education Act provides in title IV for some 1,500 national defense fellowships each year from academic year 1959–60 through the academic year 1961–62. Proposals from educational institutions to the Department of Health, Education, and Welfare for the establishment of new programs of study in oceanography (or for the expansion of existing graduate programs in this field) would be given serious consideration under the program presently authorized by the National Defense Education Act.

The key problem which we face in this whole area is that of assuring excellence in instruction in science at all educational levels. When we have come close to achieving this goal we will have less difficulty in getting enough high-quality students to take an interest in careers in science. Therefore, we need to find ways of encouraging additional students to become interested in science and then we must not only assure high-quality instruction for them, but we also should find ways of helping them get information about careers.

The National Science Foundation is concerned at present (as it has been concerned for a long time in the past) about the problem of determining relative priorities of needs in various special fields of science. The Foundation has given consideration, for example, to programs of research in problems unique to the Antarctic; it has considered as a problem area which needed special consideration the area of astronomy and, similarly, more recently, it has considered the special needs presented by the field of meteorology. Always, when these matters come up for discussion, the point is soon made that it is virtually impossible to draw up a meaningful table of priorities. What is currently the most important field of science? How does one determine which area needs help most urgently? At a given point in time is it possible to find which of the many fields that one could pick out for special attention will lead to the greatest breakthroughs in the future?

We are keenly aware of the importance of oceanography, but we are also aware of the importance of meteorology, solid-state physics, plasma physics, research on missile propulsion, or any one of many other fields. Experience demonstrates that it would be unwise to single out any one area of research and say that it is so much more important than others that it demands unusual and crash-program consideration. Hence the identification of certain limited fields of science so that they may be given special attention and special treatment is not the wise way to improve our scientific potential. Rather, we should move in the direction of providing adequate resources to assure a continuous increase in the number of young people obtaining good, basic training in the sciences at the high school and college level. These students would then be in a position to undertake graduate training in a variety of fields—not just the few that are of special importance today, but also those fields which are certain to arise and to be of crucial importance within the next 5 or 10 years. Judging from our past experience, the new fields that are yet to be developed may well prove to be more important to man's welfare than any of those we now consider so vital and so much in need of expansion.

Because science is creative, new fields of knowledge will be developed requiring more scientific personnel and research facilities. At least for the basic sciences, we believe it unwise to overplan and overdirect research and educational activities. Scientific advances are creations of men—well trained and creative—who have a strong motivation to understand the mysteries of nature. Rather than developing a kind of "Maginot line" of technology, we believe we must respond to the curiosity and competence of creative scientists, for it is these scientists who are to create the new fields of technology.

The problem of improving research and training in oceanography has been a matter of concern to the National Science Foundation for some time. We have already reached the conclusion that our efforts to secure participation in our activities by oceanographers should be expanded. We can therefore confidently predict a significant increase in our support of oceanography within the next year. Similar efforts to appraise the place of oceanography in their programs are being carried out by other Government groups, and we can expect these studies also to lead to an expansion of Federal support of this field.

To summarize, we recognize that there is a growing and recognizable need for more competent oceanographers. However, we recognize also that there are a number of fields in which we have a shortage of highly competent scientists, and our greatest effort should be made to alleviate the overall problem. We believe this can be done by interesting more of our able young people in the intellectual challenges and career opportunities in all fields of science and technology. Our approach to this problem was described to you in our previous appearance before your committee.

We also believe that we should, along with other agencies of the Federal Government, continue to study methods of support of special areas of science and technology. We will continue to make a special effort to stimulate the scientific community in these special areas by encouraging both students and scientists to apply for fellowship and research grants for support from the Foundation and by encouraging greater participation in other programs of the Foundation, including those of special field institutes, visiting scientist programs for both college and high school, summer training programs in science and engineering, career information booklets, and various other programs designed to motivate students and to increase the quality of education in the sciences.

In view of the considerations I have outlined, we do not recommend passage of H.R. 6298. We will be glad to attempt to answer any questions you may have on these matters.

Mr. BROOKS. Your opposition to H.R. 6298 is due to the fact that you think the approach to this is more basic; that is, it should begin at a lower level, and we should educate our people generally to be more interested in earth sciences, and then, with that broad base and broad background, you would approach this problem more specifically later on.

Dr. KELLY. Yes, sir. We recognize there is this shortage of highly competent men in all fields of science.

Mr. BROOKS. Do you have any thoughts in mind that you would suggest as a broadening of the base in H.R. 6298 or which would reframe or readapt that bill to be more in line with your thoughts and ideas there?

Dr. KELLY. I think what we should do, in addition to making an all-out effort in cooperation with the earth scientists, oceanographers, space science group, is to encourage the scientists and engineers to work cooperatively with our educators and teachers in high schools, help increase the quality and number of young people entering science, give sufficient research support, and this is the thing Mr. Sisk was driving at, to make the field challenging for them to get into. There must be jobs for these people or no amount of money can attract them. There must be intellectual challenges, so research must be supported, and facilities such as oceanographic vessels should be made available.

Mr. BROOKS. You refer to oceanographic vessels. You are purchasing one this year?

Dr. KELLY. We are planning that.

Mr. BROOKS. What kind of vessel is that you are going to buy?

Dr. KELLY. I would like to refer to Dr. Hanson on this.

Dr. HANSON. This is a ship to replace the *Atlantis* at Woods Hole Oceanographic Institution.

Mr. BROOKS. Is that the only vessel we have at this time?

Dr. HANSON. The only one in that budget; yes.

Mr. BROOKS. That is to replace the *Atlantis*, you say?

Dr. HANSON. That is right.

Mr. BROOKS. You will retire the *Atlantis*, then?

Dr. HANSON. That is right.

Mr. BROOKS. Then we will have one oceanographic vessel, and that is all we will have?

Dr. HANSON. Yes; in the NSF.

Mr. BROOKS. The others are with the Navy or with the Coast Guard?

Dr. KELLY. The Navy has some, and gives logistic support to this work. I believe there are about four. Perhaps we should ask Dr. Riley, if he is still here.

Dr. RILEY. The Navy recently has supplied two vessels: one to Woods Hole and another to Scripps. These are essentially replacements of old vessels. I could not tell you exactly what is the total oceanographic fleet in this country.

STATEMENT OF RICHARD C. VETTER, EXECUTIVE SECRETARY, OCEANOGRAPHIC COMMITTEE, NATIONAL ACADEMY OF SCIENCES

Mr. VETTER. There are approximately 11 seagoing oceanographic research ships that are now being used by private, nonprofit oceanographic institutions. All of these are obsolete and, with one exception, the *Atlantis*, they are conversions of other types of ships to oceanography purposes.

Dr. KELLY. I want to refer to this report which the Committee made.

Mr. BROOKS. I read that report.

Dr. KELLY. On page 12 there would be an answer to your question of the total fleet. It is in book 1 of "Oceanography, 1960 to 1970." Would you like this placed in the record?

Mr. BROOKS. Would you read the portion you have in mind?

Dr. KELLY. Here is the 10-year plan for increasing the U.S. fleet of oceanographic ships. The present fleet research vessels number 11; military research and development, 9; survey, 18; research and fisheries, 7; totaling 45.

Mr. BROOKS. So, the fleet would consist of 45.

Mr. CARSTARPHEN. Mr. Chairman, this is Richard C. Vetter, Executive Secretary of the Oceanographic Committee of the National Academy of Sciences who is thoroughly familiar with the reports presently under discussion.

Mr. BROOKS. Who has control of those 45 vessels?

Mr. VETTER. We have another report which has just been printed which gives more detail regarding the problem of oceanographic research ships.

Mr. BROOKS. Have you enough copies of those?

Mr. VETTER. It was published this week. I do not have copies.

Mr. BROOKS. Can you let us have copies?

Mr. VETTER. Yes; I will.

Mr. BROOKS. And the other copy of the work on oceanography we can get for the members of the committee. I read it, and I think most of the members have seen it.

Mr. VETTER. Briefly, the answer to your question is that the oceanographic research fleet, of which there are 11 seagoing ships now, is mainly in control of nonprofit oceanographic institutions or universities. In addition to that, there are nine larger research ships that are classified as military research and development vessels. These are in

control of the Navy, operating out of Navy laboratories. There are approximately 18 ships mainly devoted to survey activities, and these are mixed between the Coast and Geodetic Survey and the Navy. There are also about seven ships devoted mostly to fisheries research activities, and these are entirely under the control of the Bureau of Commercial Fisheries.

Mr. BROOKS. We do not have jurisdiction of the fisheries, as I understand it. Tell me this: You have divided jurisdiction over oceanography. Would it be preferable if that fleet were under one direction and control?

Mr. VETTER. Are you directing that question to me, sir?

Mr. BROOKS. Yes.

Mr. VETTER. I think not, sir. I believe I reflect the feeling of the members of the Committee on Oceanography in this respect——

Mr. BROOKS. You mean this committee?

Mr. VETTER. The National Academy on Oceanography, who wrote this report.

Mr. BROOKS. All right.

Mr. VETTER. In oceanography there needs to be a close association between the groups that need the information and the groups that are producing the information, and we do not recommend that there be one central mechanism for controlling, say, all the ships that do oceanographic research, because there are many departments of the Government that have direct and very personal interest in particular types of problems, and they should have the ability to see that their own interests are carried out.

In particular, I do not think it would be wise to put together the research ships doing work for the Navy and the research ships working for the Bureau of Commercial Fisheries. Their interests are different, and they should have the flexibility of carrying out additional and slightly different types of work.

Mr. BROOKS. Navy ships are manned by Navy crews, are they not? The commercial ships are manned by commercial crews.

Mr. VETTER. That is right. There are no commercial ships involved here, in terms of reference to which you refer. The fisheries ships are all manned by civil service crews, as are the Coast and Geodetic Survey ships.

Mr. BROOKS. Are all of these vessels manned by Government employees?

Mr. VETTER. No, sir. Research ships are manned by private citizens who work and are directly employed by the oceanographic institutions. The military research and development ships, fisheries ships, or others, in one way or another, are manned by Government workers.

Mr. BROOKS. Any further questions?

Mr. HECHLER. I am impressed with the need for the National Science Foundation to move forward more aggressively in this entire field. I would like to pose this question: Is it not true that knowledge in the oceans which we do not now have could really be critical and crucial to our national defense in the future?

Mr. VETTER. It certainly is. I think this is the very essence which brings this subject to attention at this time. It is a very critical situation. The analogy which one of the committee members made before is that by obtaining more information about the environment in

which the Navy has to operate and the fisheries groups have to operate, we can expect to increase the efficiency by 100 to 200 percent.

The Navy is entirely dependent upon a vast amount of oceanographic information for the effectiveness of its operations. The ability to forecast oceanographic parameters would be of tremendous value to the Navy, as it would be to fisheries groups.

Perhaps the homeliest analogy you can draw is to compare the success that the Indians had in resisting, and in fighting with, the settlers. They were able with inferior weapons and with inferior communications to quite often very seriously inflict damage upon more highly organized and well-equipped troops simply because they knew their way around the woods much better and could find hiding places and mechanisms of attack that were unknown and unappreciated by the paleface from the city.

It is the same in the oceans. The nation which becomes intimately aware of all the potentialities of finding its way around the oceans will have a tremendous advantage over the group which does not have this capability.

Mr. HECHLER. What about knowledge of the effects of nuclear explosions, for example, with oceanography contributing some part to that?

Mr. VETTER. Most definitely. I believe the range at which these explosions are effective is determined to a large extent by the density structure in the oceans. Because of the layering of density within the oceans there is a phenomenon of focusing of acoustic energy or pressure energy within the refraction process. This focusing can do very strange things to a pressure wave and can have a great deal of effect upon the effectiveness or lack of effectiveness of any type of such disturbance, whether it be nuclear explosion or just an acoustic transmission.

Mr. HECHLER. Thank you. Although I am not presently in support of H.R. 6298, I would say that if, after a reasonable period of time, the National Science Foundation does not demonstrate an aggressive interest in this field I may swing around back to supporting this bill.

Mr. BROOKS. In line with what Mr. Hechler has been asking you, I want to ask this: I have heard it said that the Polaris submarine, for instance, would not be maneuverable or not be able to operate in the seas unless we have a better knowledge of oceanography. Would you make any statement in reference to that?

Mr. VETTER. I will say that in the Navy those individuals that are most in favor of a dynamic and aggressive program in oceanographic research are submarine officers. These men are very much aware of the advantage that they have by additional knowledge of their environment, and certainly the Polaris missile concept is a very highly refined weapons system which is very susceptible and very dependent upon the ocean environment. I would not say it will not operate without this knowledge, but it certainly will be very dependent upon this information.

Mr. BROOKS. And that would be the reason, would it—at least it would be one of the reasons—that you use for stating you did not want a unified control of your oceanographic fleet?

Mr. VETTER. Yes, sir; I believe so.

Mr. BROOKS. Any further questions?

Mr. KARTH. Mr. Chairman, I think Dr. Kelly has made a fine statement.

If I understood your position correctly, your position is that there are now avenues which can be used by people who are interested in becoming oceanographers that are not fully being utilized.

Dr. KELLY. That is right.

Mr. KARTH. And, No. 2, this whole program of the sciences is much broader than merely oceanography, and therefore you support the theory that first things come first and the first thing in your opinion is that we must broaden the teacher responsibilities or teacher training in this whole field of the sciences and approach it from that standpoint, which eventually will solve many of our problems, not only in oceanography but the overall scientific field. Do I state your position correctly?

Dr. KELLY. Yes, sir. Might I add one more thing? We are also a new organization. Our budget is going up, and just this year, thanks to this committee, we got some blessings in the way of things we think should be done in science. This committee gave us freedom and at the same time responsibility in increasing our efforts in direct support of science and education in the sciences.

Mr. BROOKS. I think everybody on the committee wants to keep on giving you a push.

Dr. KELLY. So that we can get into these areas with time. We began with a very low amount of money in our first year, and as our budget does increase——

Mr. KARTH. Is that not primarily your problem? You have about all the authority you need. You can get involved in as many fellowships as you can financially support. Is that true? All you need is the money from Congress to do these things that are being suggested?

Dr. KELLY. Yes, sir.

Mr. KARTH. You have the authority and the potential.

Dr. KELLY. Yes, sir.

Mr. KARTH. You have the manpower in your own department. You feel you can accomplish not only oceanographic studies, but other scientific advancements which we realize we must make. You can accomplish these things with money; is that correct?

Dr. KELLY. Yes. We think, with the passage of the new amendment, we do have this authority. Might I add something else to make sure Mr. Hechler will not be disappointed with us when he looks to see whether we have really stimulated these special areas?

Please remember that we are not a military agency. We are supporting basic research in education of the sciences. The problem I have heard discussed involved submarine detection, sonar, and the like. We think this is a function of the U.S. Navy, and not the National Science Foundation. Basic research, which includes earth sciences and oceanography, falls on us, but not the military applications.

Mr. BROOKS. One moment, Doctor—of course, the application of the principles are the problems of the Navy, but the actual study of earth sciences surely is your problem.

Dr. KELLY. Yes, sir.

Mr. BROOKS. Oceanography is merely one of the earth's sciences, is it not?

Dr. KELLY. That is right.

Mr. BROOKS. When you develop oceanography you certainly would not keep from the Navy or the other Defense Department services information which they need for the proper handling of their vessels and submarines?

Dr. KELLY. Indeed not. Some of the applications are being supported by the military and we see no reason why they should not be. Basic knowledge about the oceans, physics, chemistry, and biology we would and do support.

Mr. BROOKS. Would you say that Matthew Fontaine Maury, who is a Navy man, by the way, is the first outstanding individual in this country who began a study of the ocean depths? Was he the forerunner of the science of oceanography?

Mr. VETTER. We can put that hat on him; yes.

Dr. RILEY. Ben Franklin was perhaps the first one. He made significant contributions.

Mr. BROOKS. Would you put Maury in there at all?

Dr. RILEY. Indeed, I would.

Mr. BROOKS. He is one of the ones who in this country started the science of oceanography. Any further questions?

(No response.)

Mr. BROOKS. If not, we certainly thank you, gentlemen, because this morning the work was more or less exploratory.

I would like to ask members of the committee to remain with me a few moments in executive session.

We will thank all of you for being here this morning and giving such fine contributions to the work of this committee.

(Whereupon the committee adjourned at 12 noon.)

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